

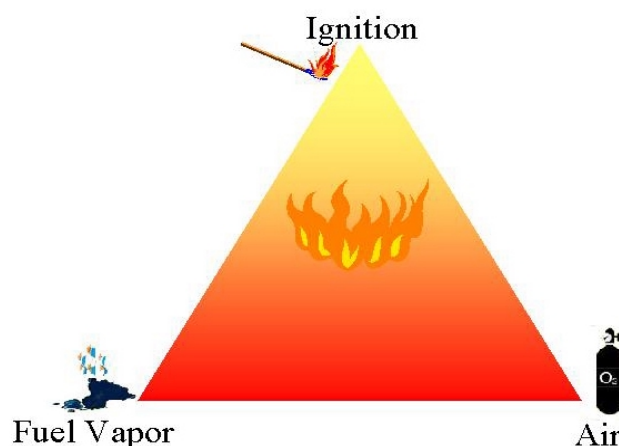
Fuel Tank Safety

The TWA Flight 800 accident focused attention on fuel tanks as a significant safety issue. The question asked in previous incidents of fuel tank explosion was, "What ignition source caused the explosion?" This question was consistent with the FAA's prevailing philosophy that minimizing ignition sources was the best way to avoid a fuel tank explosion. However, in the case of TWA Flight 800, the ignition source was—and is—unknown.

The "Fire Triangle"

Combustion, by definition, is the reaction of fuel vapor and oxygen, when heated by an ignition source. These three elements form a "fire triangle."

Fuel vapor from jet fuel is a function of temperature. If the temperature of the fuel is too low, not enough vapor is created for combustion. If the temperature of the fuel is too high, too much vapor is created, which interferes with combustion. The range in between these two points is called the "flammability envelope." The size and position of the flammability envelope is affected by the type of fuel, the oxygen content of the air, and the ignition energy.



Fuel vapor, air, and an ignition source form the "Fire Triangle."

Reducing the Risk of Fuel Tank Explosions

Due to the nature of combustion, there are three possible approaches to reducing the risk of fuel tank explosions:

1. Reduce the Flammability of Fuel Vapor

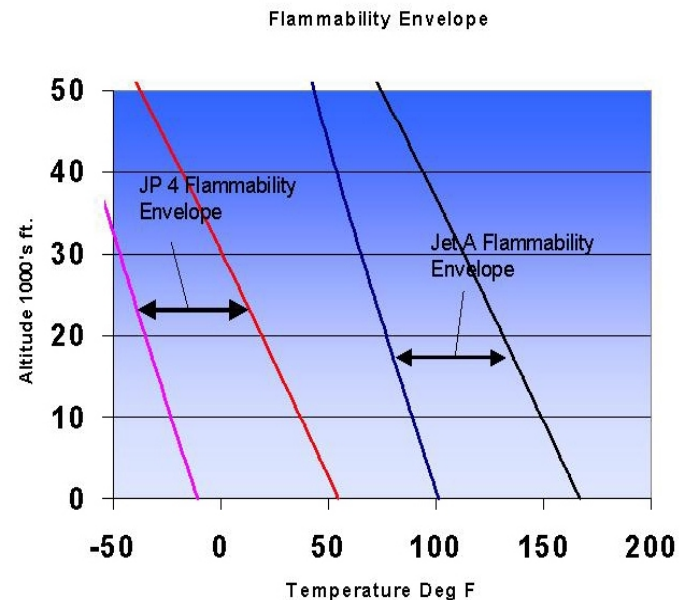
Early jet engines could burn a variety of fuels. Depending on the characteristics of the fuel, the fuel tank could be flammable at any point. By the early 1970s, commercial airplanes standardized to use Jet A fuel, which was less flammable than other fuels.

2. Reduce the Oxygen in the Fuel Tank

Reducing oxygen in the fuel tank through an inerting system has been effective on military aircraft for decades. However, research showed that such systems were too heavy and too expensive to be practical for commercial airplanes.

3. Eliminate Ignition Sources

Given that the other possible approaches were not feasible, the FAA has historically focused on minimizing ignition sources to prevent fuel tank explosions.



The FAA's Fuel Tank Safety Mission

The FAA has a two-pronged approach to fuel tank safety:

1. Aggressively prevent ignition sources
2. Minimize fuel tank flammability

Aggressively Preventing Ignition Sources

The chart on this page summarizes the FAA's recent activities toward aggressively finding and eliminating ignition sources. The photos on this page show discrepancies that were found as a result of these activities and rapidly corrected before they caused an accident.



Conduit with arc-through

Since 1996, the FAA has published more than 50 ADs to prevent ignition sources in fuel tanks. These ADs have applied to most airplane models in the fleet and cover a range of issues, including pump manufacturing discrepancies, wire chafing, protection of the fuel quantity indication system, and overheating solenoids.

Pump housing with arc-through



	1997	1998	1999	2000	2001	2002	2003
Airworthiness Directives							
	50+ ADs issued, covering most commercial airplane models (ongoing)						
Workshops/seminars		FAA only (Calverton)	JAA workshop FAA workshop (Renton)		Seattle	Amsterdam	Chicago Washington, DC
			DER seminars with ACOs				
SFAR 88	First SFAR announcement		SFAR 88 NPRM published		SFAR 88 Final Rule published		Safety review results due to FAA

In a far-reaching systemic review of fuel systems through SFAR 88, the FAA asked manufacturers, supplemental type certificate-holders, and operators to thoroughly review each airplane model to find potential ignition sources. They used very conservative criteria and considered what has been learned since the TWA Flight 800 accident.

The results of the systemic review of fuel systems are due to the FAA in December 2002. FAA experts will examine these reviews to determine potential revisions to existing designs.

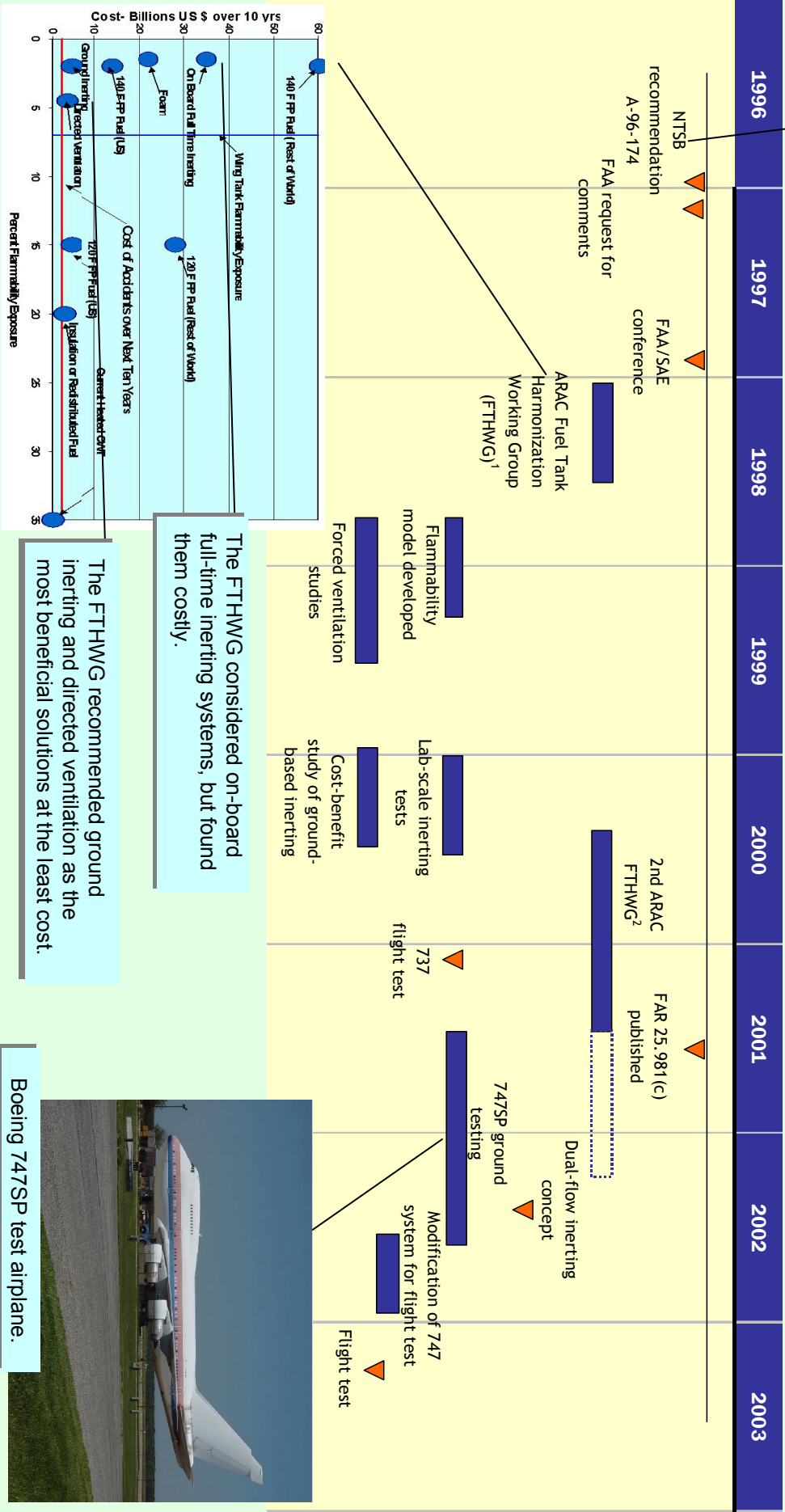


Frayed fuel pump wire

Pursuing Flammability Reduction

The chart on this page summarizes the FAA's recent activities in reducing the flammability of fuel tanks.

Based on the TWA Flight 800 investigation, the National Transportation Safety Board (NTSB) recommended that the FAA require the development and implementation of design or operational changes to preclude the operation of transport category airplanes with explosive fuel-air mixtures in the fuel tank. The NTSB recommended that the FAA give significant consideration to developing airplane design modifications such as nitrogen inerting systems for use on newly certificated airplanes and, where feasible, existing airplanes.



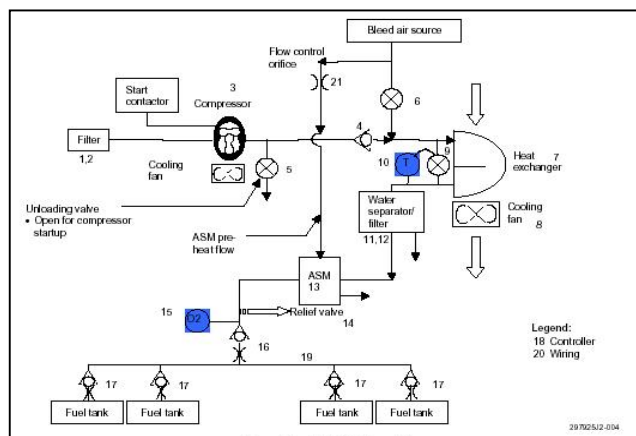
- 1 Report recommended research and development on ground inerting and forced ventilation.
- 2 Report stated that inerting was too expensive, and more research and development was needed.

Flammability Reduction Research

The Aviation Rulemaking Advisory Committee (ARAC) Fuel Tank Harmonization Working Group targeted heated center fuel tanks, as they are far more likely to explode than unheated wing tanks.

As a result of the FAA's continued research into inerting systems, a second ARAC Working Group was tasked to investigate potential inerting systems and recommend rulemaking. This second Working Group found that an on-board inerting system, such as the military had used, showed promise but judged such a system to be too heavy, complicated, unreliable, and costly.

Military airplanes like the C-17, C-5, and XB-70 use inerting systems to prevent fuel tank explosions.



The second ARAC Working Group envisaged a complex system design that would be impractical.



Inerting Systems

An inerting system replaces the oxygen in the fuel tank with an inert gas such as nitrogen, preventing the ignition of fuel vapor.

Inerting systems have been used on military aircraft since World War II. From that time to the present, inerting of the fuel tanks has been used to minimize combat explosions and battle damage. On high-speed airplanes such as the XB-70, an inerting system was used to prevent ignition of the fuel due to the heating effects of supersonic speed.

Many different techniques have been used in the inerting systems on military aircraft. On World War II-era airplanes, exhaust was typically used to produce the inert gas. More recently, nitrogen has been used to render the fuel tank inert. Various techniques exist for separating nitrogen for use in inerting, the simplest and most reliable being the membrane technology that is used in the FAA-developed inerting system.

A Practical Inerting System

In spite of the ARAC Working Groups' findings, the FAA continued researching and developing an inerting system for fuel tanks. In May 2002, a significant breakthrough occurred in the development of a viable and practical on-board inerting system. This system uses bleed air flow, which eliminates the need for separate compressors and motors; 12 percent oxygen as an inerting level instead of the 10 percent tasked to ARAC; a simple in-tank distribution system; and a dual-flow mode to manage nitrogen flow into the tanks. For testing, the FAA has installed a working system on a Boeing 747SP, and data show the system to be effective. While the FAA continues its research and development efforts, one manufacturer has already recognized the value of the FAA's breakthrough and is pursuing fast-track development of an inerting system.

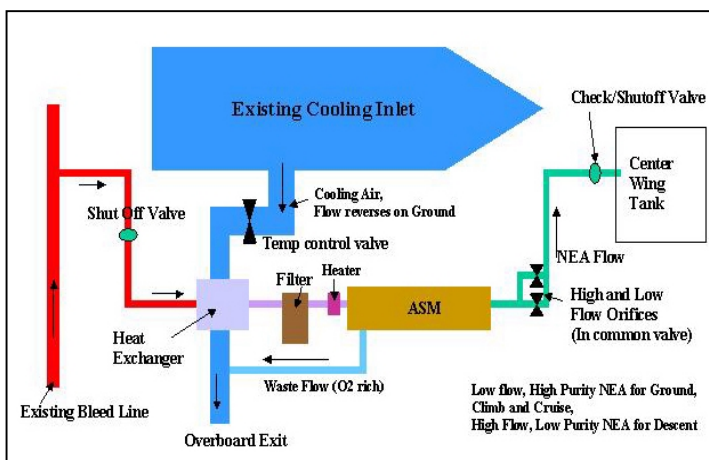
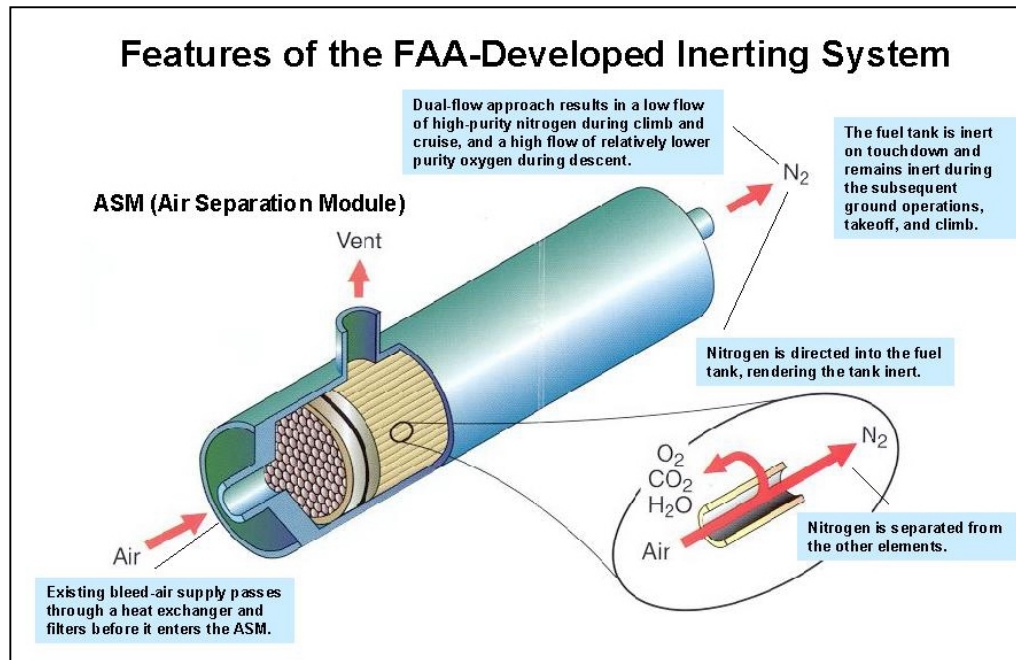


Diagram of simple inerting system developed by the FAA.

Inerting system installed on Boeing 747SP test airplane.

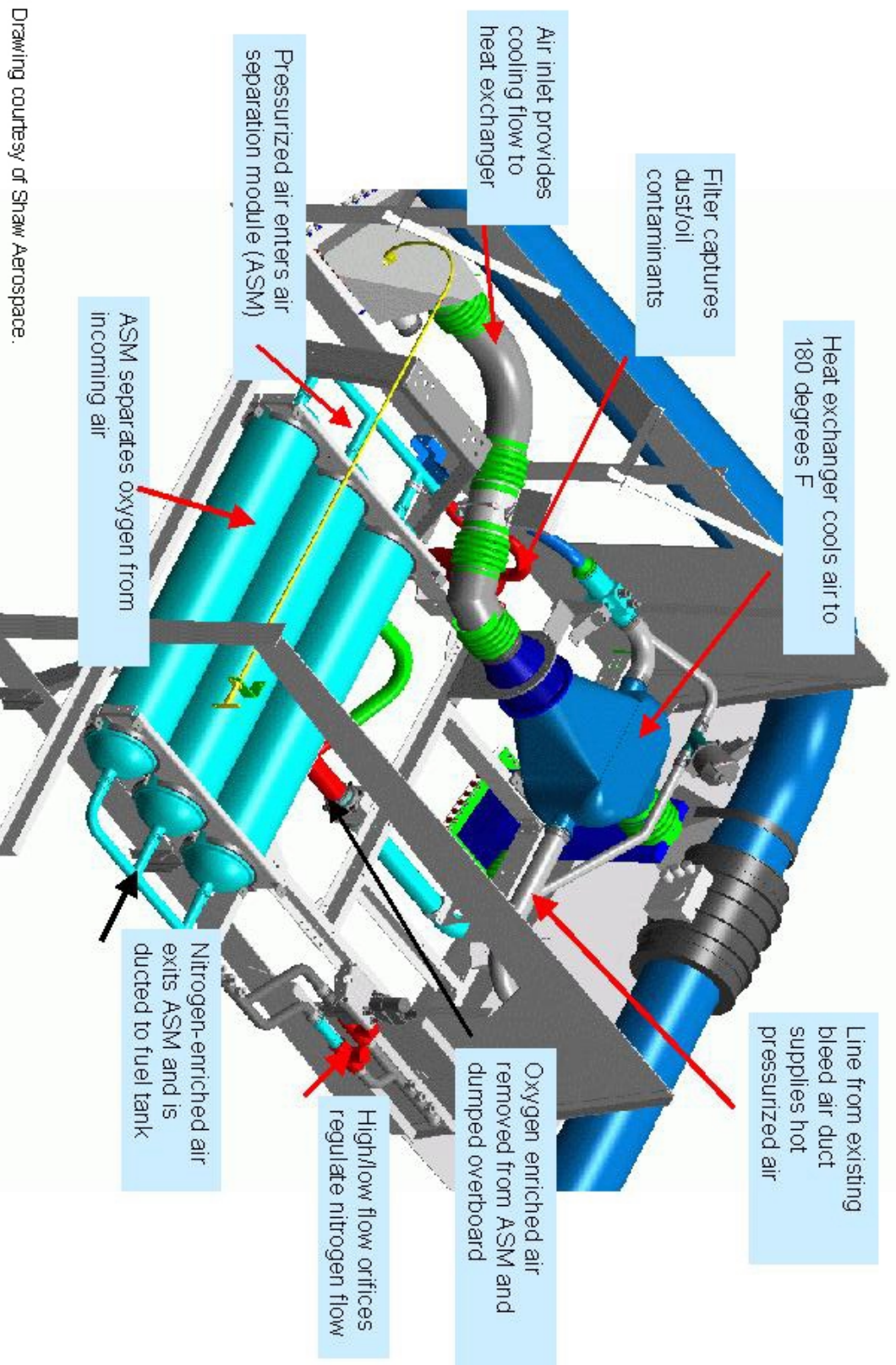


In the past six years, the FAA has made great achievements in fuel tank safety, first through rulemaking actions targeted toward minimizing potential ignition sources, and now, through a technological breakthrough that has made a practical fuel tank inerting system a reality. As we work toward using inerting systems to eliminate fuel tank flammability, we will continue to minimize potential ignition sources.



The FAA continues to believe that the ultimate solution to fuel tank safety is a balanced approach of ignition prevention and flammability reduction.

747SP Inerting System



Drawing courtesy of Shaw Aerospace.